BEST AVAILABLE COPY

(12) UK Patent Application (19) GB (11) 2 296 151 (13) A

(43) Date of A Publication 19.06.1996

(21) Application No 9425607.0

(22) Date of Filing 16.12.1994

(71) Applicant(s)
Sharp Kabushiki Kaisha

(Incorporated in Japan)

22-22 Nagaike-cho, Abeno-ku, Osaka 545, Japan

(72) Inventor(s)
Graham John Woodgate
Jonathan Harrold
David Ezra
Basil Omar
Edward Peter Raynes

(74) Agent and/or Address for Service
Marks & Clerk
Alpha Tower, Suffolk Street Queensway,
BIRMINGHAM, B1 1TT, United Kingdom

(51) INT CL^6
H04N 13/04

(52) UK CL (Edition O)
H4F FDD FD15 FD27C1 FD27P FD27S FD27T1 FD27X FD30K FD42V FD42X FD83B

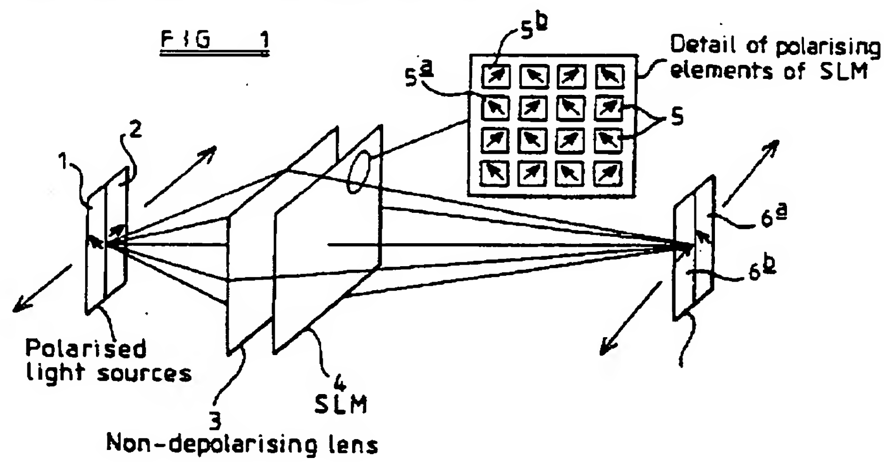
(56) Documents Cited
EP 0541374 A1

(58) Field of Search
UK CL (Edition N) H4F FDD
INT CL^6 H04N 13/00 13/04 15/00
Online: WPI

(54) Autosteroscopic display device

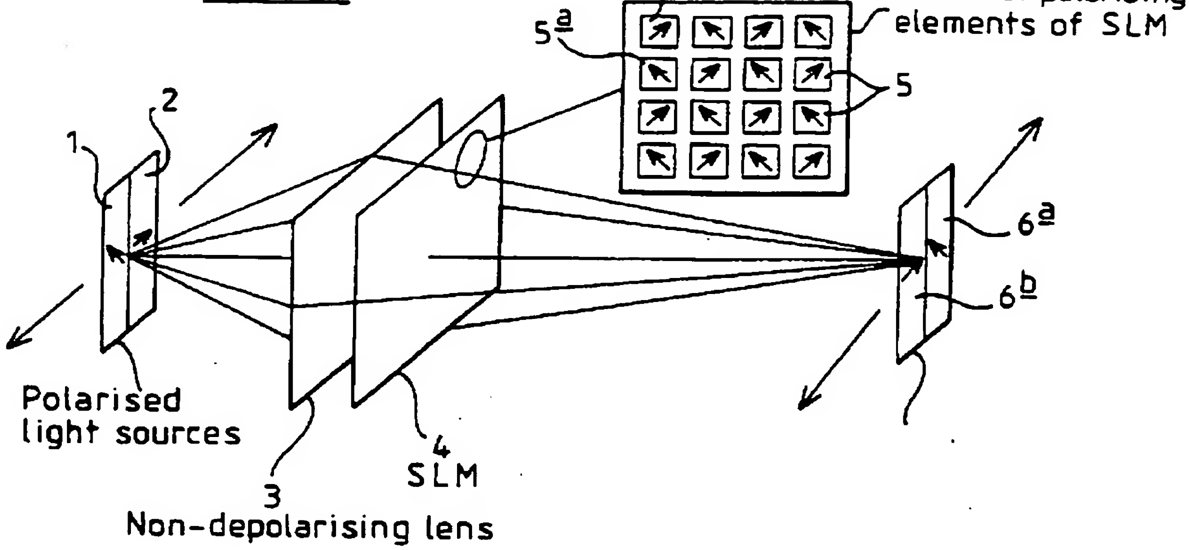
(57) A display device comprises a source 1 of light of a first polarization, a source of light of a second polarization different from the first polarization and an optical system to image the light emitted by the light sources through a spatial light modulator (SLM) to produce an image of the source of light of the first polarization at a first viewing zone 6a and an image of the second source of light at a second viewing zone 6b. The SLM includes a plurality of picture elements arranged to modulate the light emitted by the light sources and a plurality of polarization adjusting means each optically aligned with at least one respective picture element, comprising a first group permitting only the transmission of light of the first polarization and a second group permitting only transmission of light of the second polarization such that the image on the SLM which can be viewed from the first viewing zone is that of the picture elements optically aligned with the first polarization and the image which can be viewed from the second viewing zone is that of the picture elements optically aligned with the second polarization. The polarization adjusting means may comprise an array of either polarizing elements 5a, 5b or wave plates (Fig 8, 33).

FIG 1



GB 2 296 151 A

FIG 1



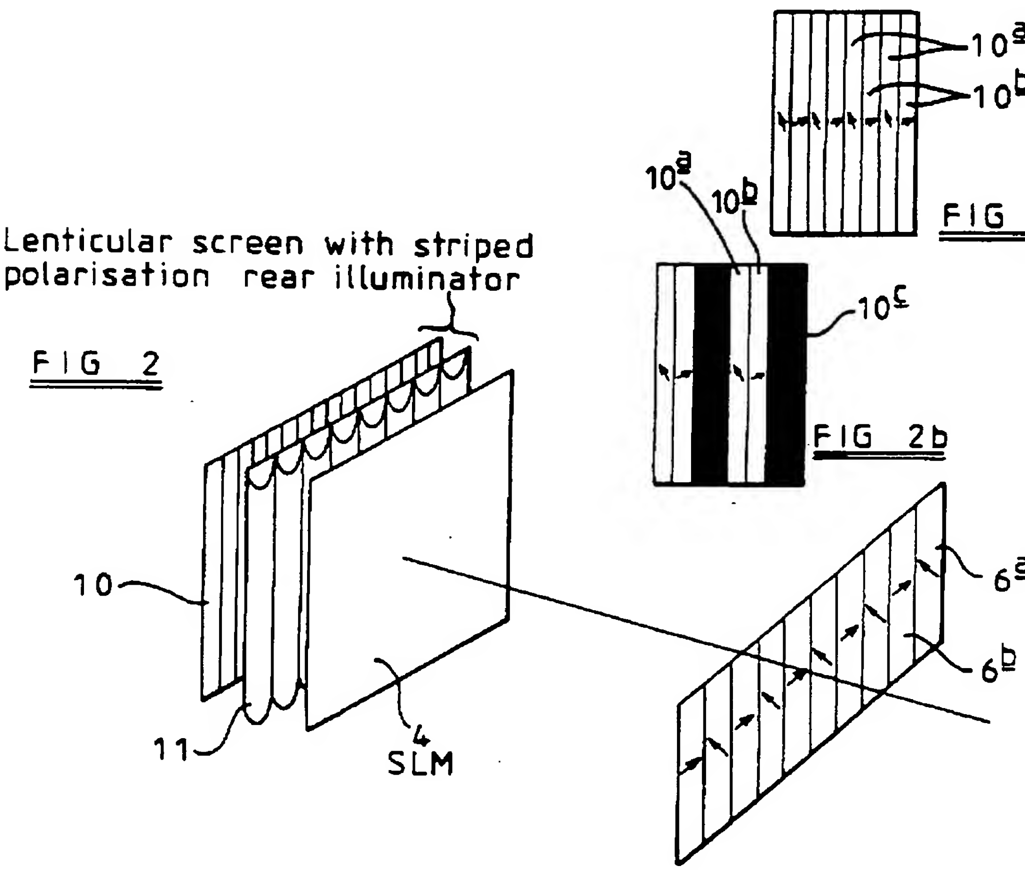
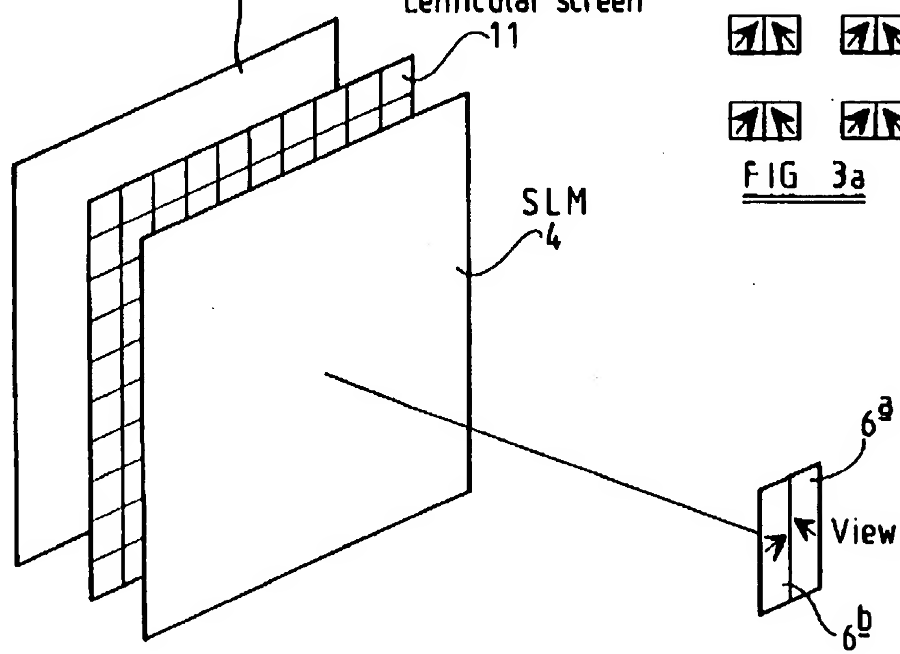


FIG 2a

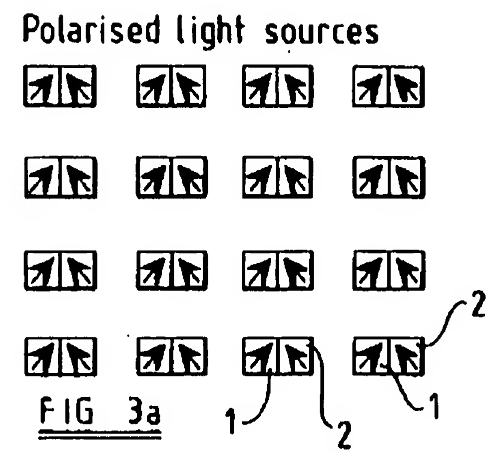
FIG 2b

FIG 2

FIG 3



Polarised light sources
Lenticular screen
11
SLM
4
6a
Viewing positions
6b



Polarised light sources
2
1
2
1

FIG 3a

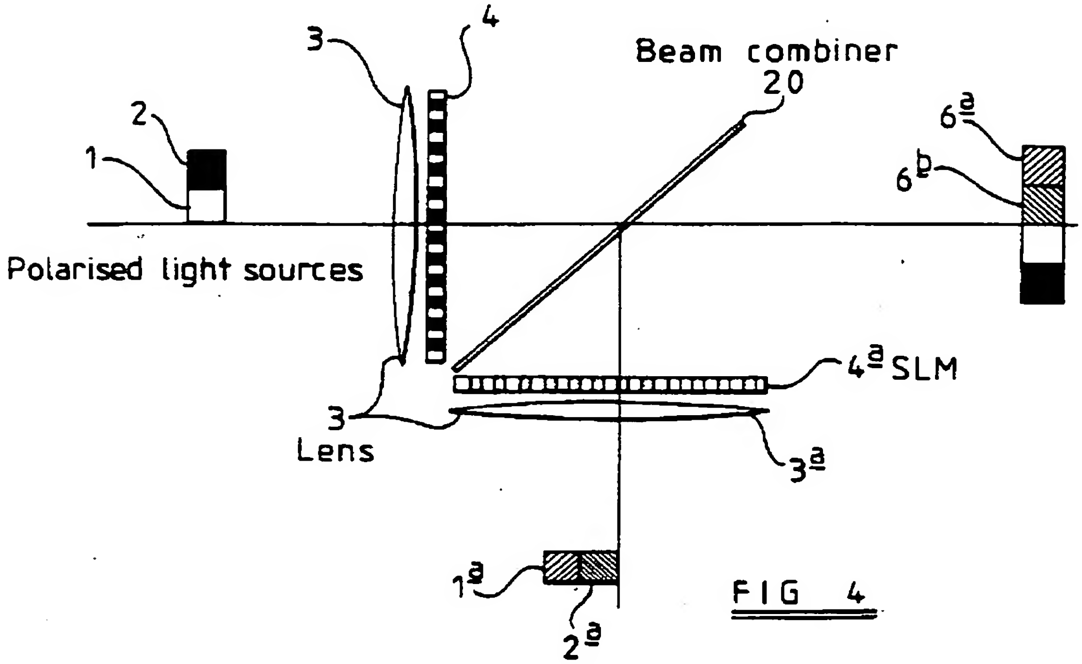

Beam combiner
20
4
3
2
1
6a
6b
Polarised light sources
4a SLM
3
Lens
3a
1a
2a

FIG 4

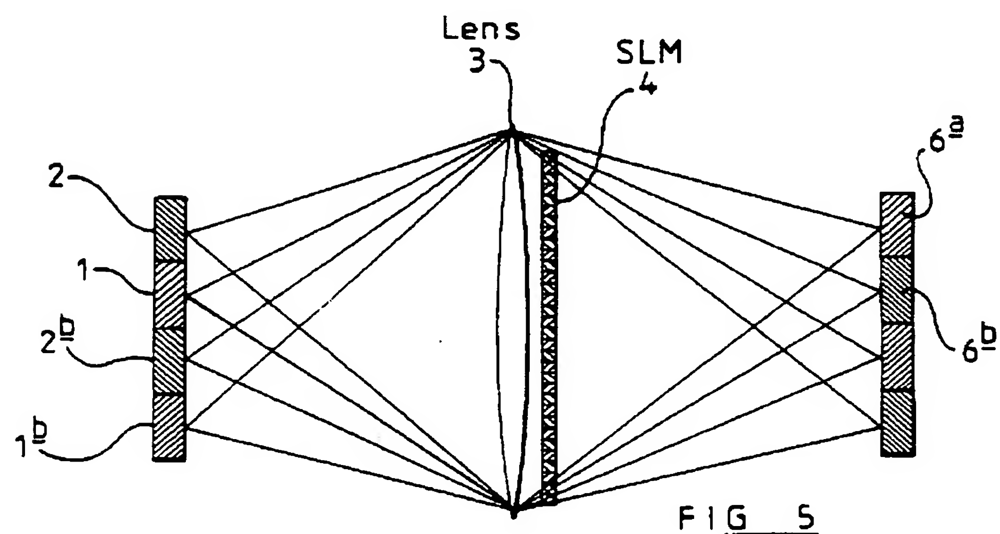

Lens
3
SLM
4
2
1
2b
1b
6a
6b

FIG 5

FIG 6

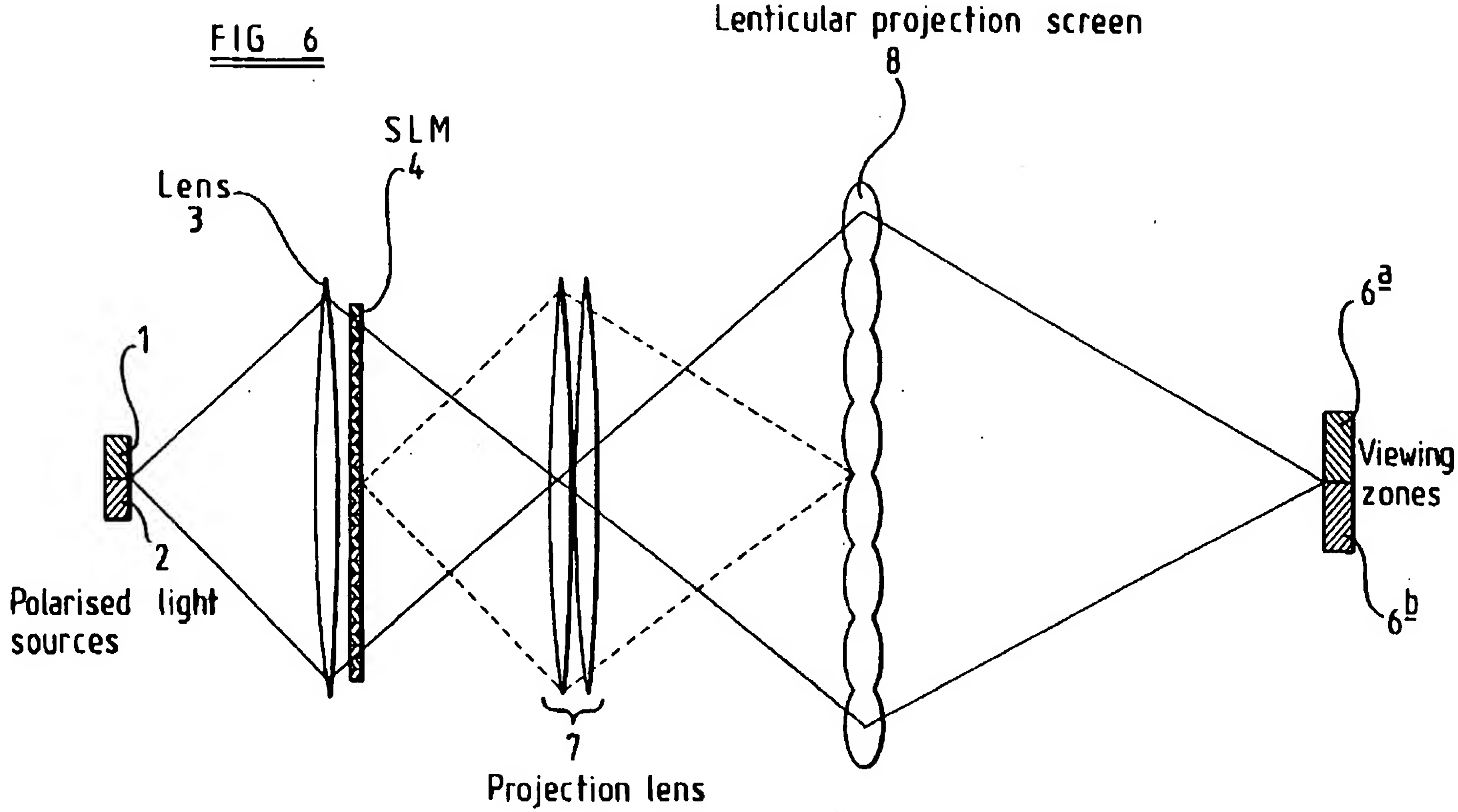

Lenticular projection screen
8
SLM
4
Lens
3
1
2
Polarised light sources
7
Projection lens
6a
Viewing zones
6b

FIG 7

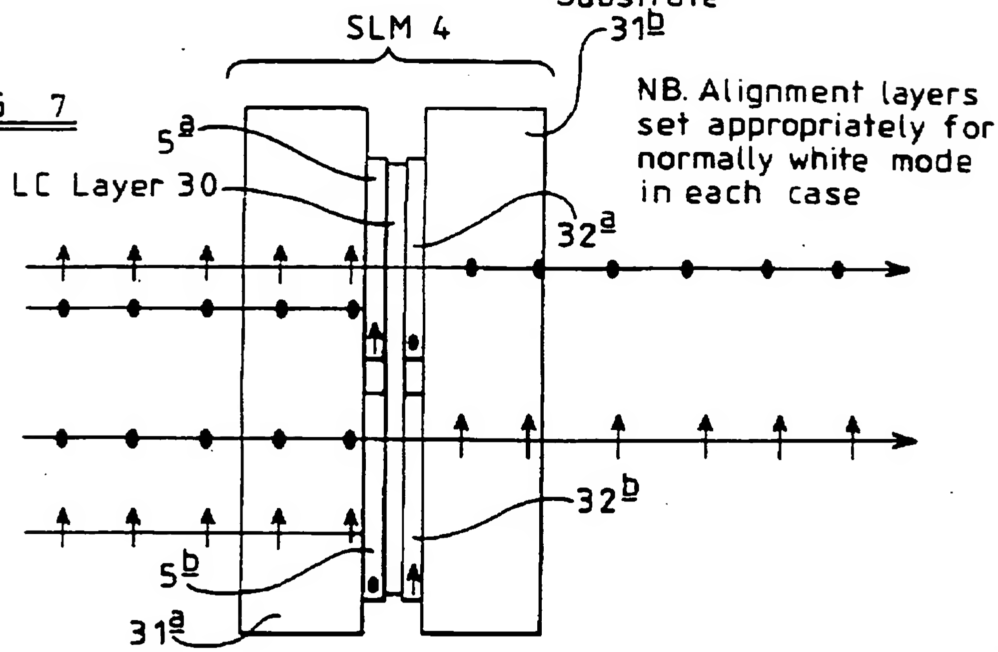
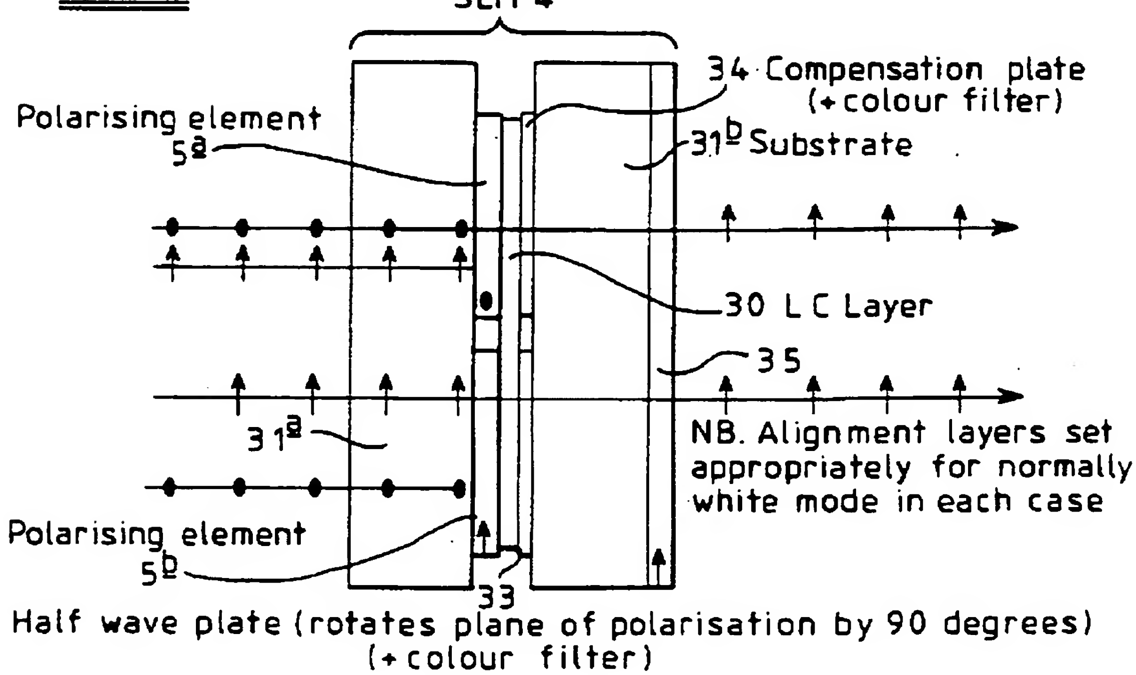

SLM 4
Substrate
31b
NB. Alignment layers set appropriately for normally white mode in each case
5a
LC Layer 30
32a
32b
5b
31a

FIG 8


SLM 4
34 Compensation plate (+colour filter)
Polarising element 5a
31b Substrate
30 LC Layer
35
31a
NB. Alignment layers set appropriately for normally white mode in each case
Polarising element 5b
33
Half wave plate (rotates plane of polarisation by 90 degrees) (+colour filter)

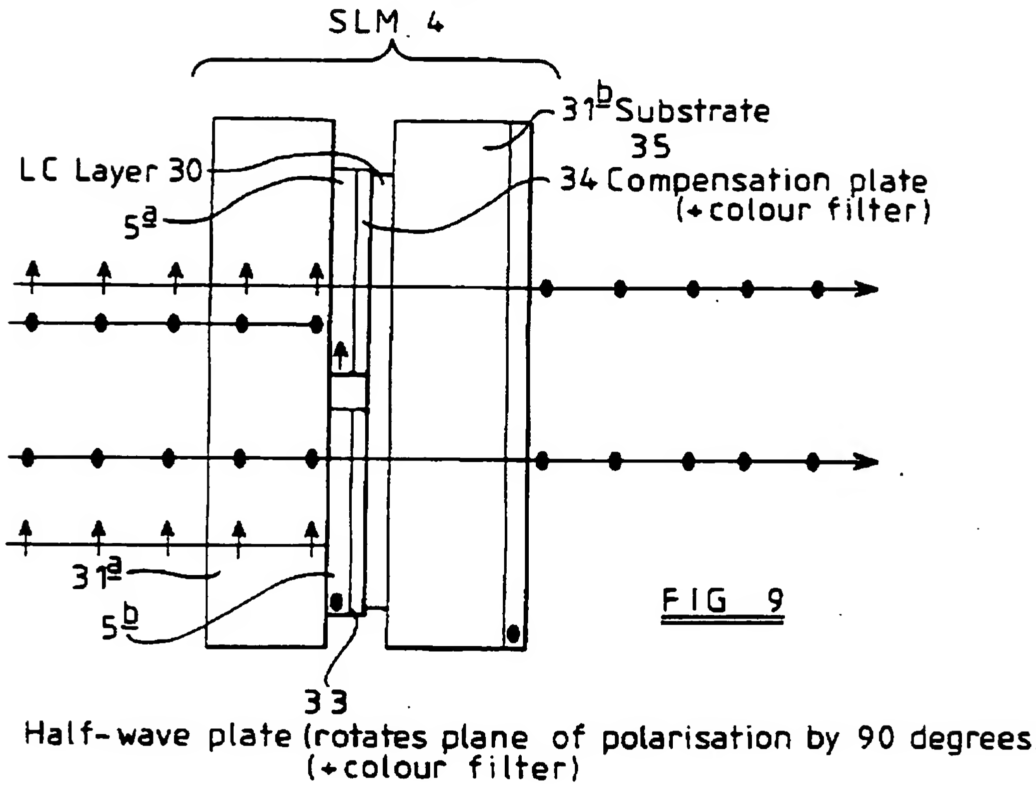

SLM 4
31b Substrate
35
LC Layer 30
34 Compensation plate
(+colour filter)
5a
31a
5b
33
Half-wave plate (rotates plane of polarisation by 90 degrees)
(+colour filter)

FIG 9

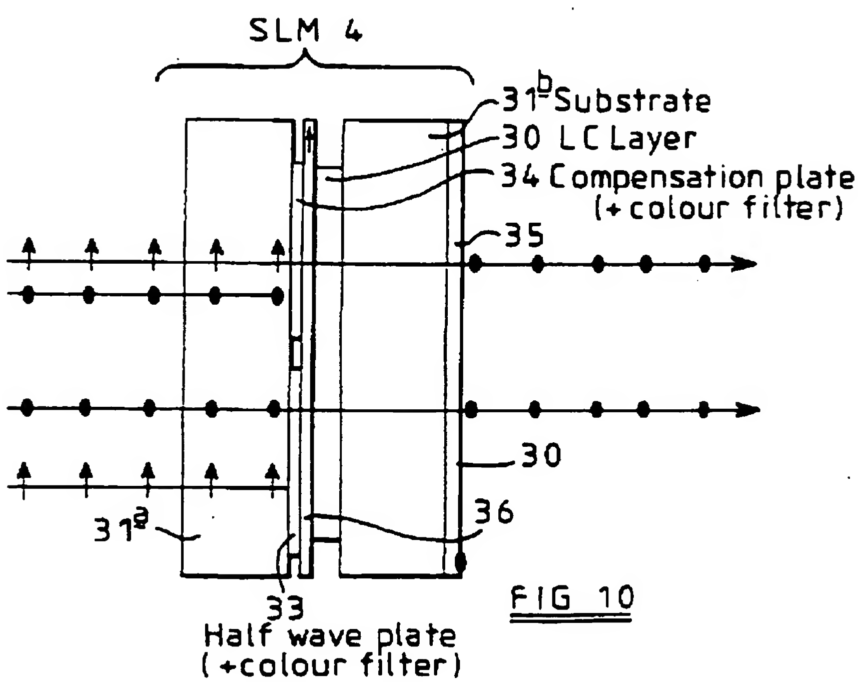

SLM 4
31b Substrate
30 LC Layer
34 Compensation plate
(+colour filter)
35
30
36
31a
33
Half wave plate
(+colour filter)

FIG 10

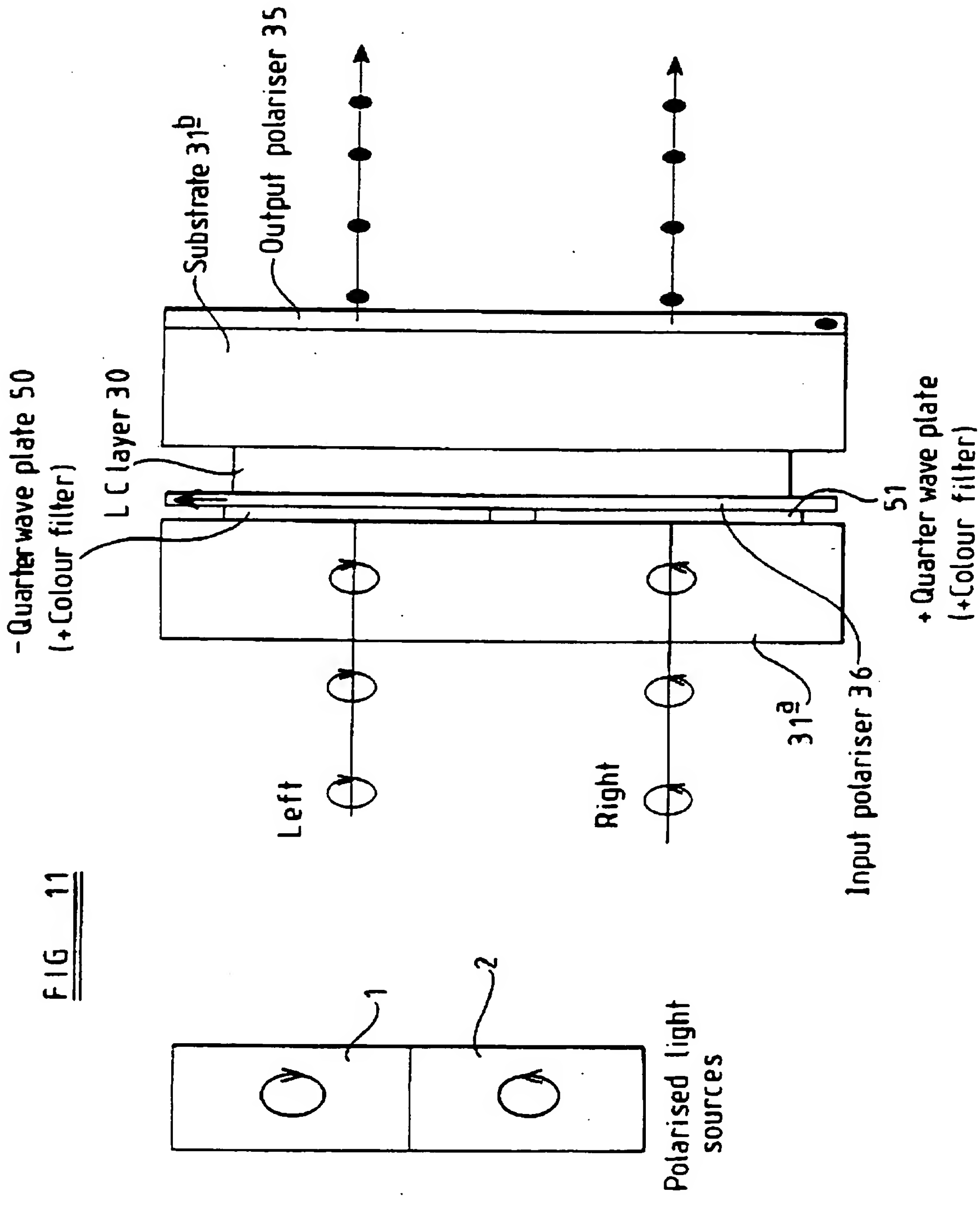

Output polariser 35
Substrate 31b
L C layer 30
- Quarter wave plate 50
(+ Colour filter)
51
+ Quarter wave plate
(+ Colour filter)
31^a
Input polariser 36
Left
Right
1
2
Polarised light
sources

FIG 11

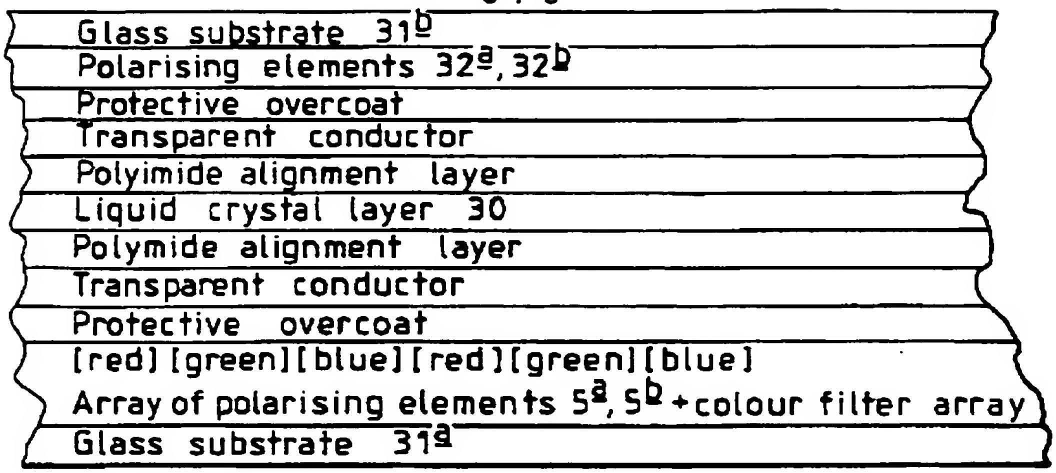

Glass substrate 31^b
Polarising elements $32^a, 32^b$
Protective overcoat
Transparent conductor
Polyimide alignment layer
Liquid crystal layer 30
Polymide alignment layer
Transparent conductor
Protective overcoat
[red] [green] [blue] [red] [green] [blue]
Array of polarising elements $5^a, 5^b$ + colour filter array
Glass substrate 31^a

FIG 12

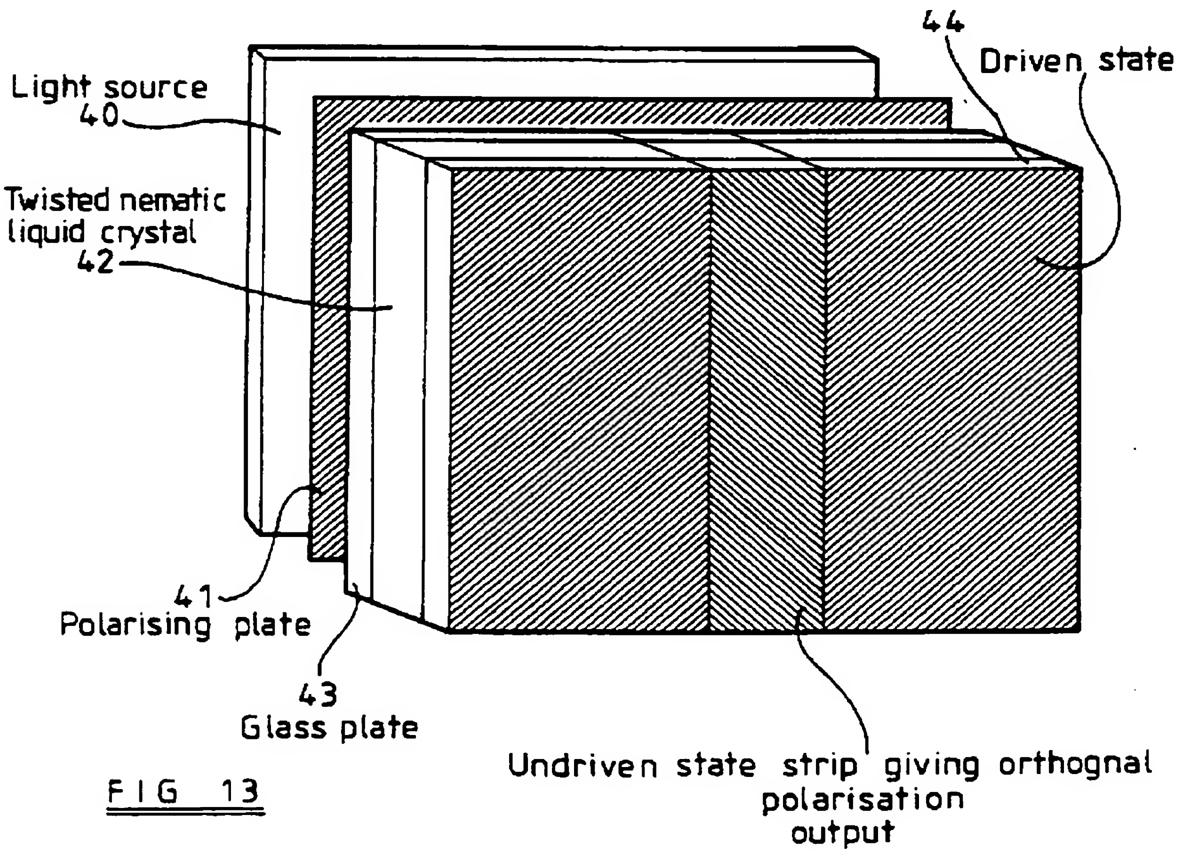

44
Driven state
Light source
40
Twisted nematic
liquid crystal
42
41
Polarising plate
43
Glass plate
Undriven state strip giving orthognal
polarisation
output

FIG 13

2296151

AUTOSTEREOSCOPIC DISPLAY DEVICE

This invention relates to an autostereoscopic display device for use in producing three dimensional display, autostereoscopic displays not requiring the use of viewing aids.

A number of display devices have been disclosed which are capable of producing a stereoscopic display, but which require an observer to use viewing aids, commonly in the form of glasses. In one arrangement (J. Opt. Soc. Am. 30:230, 1940), the observer wears glasses incorporating polarized lenses, the axes of polarization of the lenses being crossed. When viewing an image including polarized regions using the glasses, the images seen by one of the observers eyes is different to that seen by his other eye.

In Advanced Imaging, May 1992, pages 18 to 22, a device is described in which two halves of a stereographic image are interlaced and displayed using a liquid crystal display positioned behind a parallax barrier which consists of opaque regions of crossed micropolarizers and transparent regions therebetween. The pitches of the interlaced images and the barrier are such as to define first viewing positions at which a first of the halves is visible and second viewing positions at which the other half is visible. If an observer is positioned so that one of his eyes is at one of the first viewing positions and his other eye is at one of the second viewing positions, the stereographic image can be viewed. The function of the micropolarizers is to form a parallax barrier, the polarization of the light transmitted thereby being substantially unchanged.

According to the invention there is provided a display device comprising a source of light of a first polarization, a source of light of a second polarization different from the first polarization, an optical system arranged to image the light emitted by the light sources through a spatial light modulator (SLM) to produce an image of the source of light of the first polarization at a first viewing zone and an image of the second source of light at a second viewing zone, the SLM including a plurality of picture elements arranged to modulate the light emitted by the sources of light, and a plurality of polarization adjusting means each being optically aligned with at least one respective picture element, the polarization adjusting means comprising a first group arranged to permit the transmission of light of the first polarization and substantially prevent transmission of light of the second polarization, and a second group arranged to permit the transmission of light of the second polarization and substantially prevent transmission of light of the first polarization such that the image on the SLM which can be viewed from the first viewing zone is that of the picture elements optically aligned with the polarization adjusting means of the first group and the image which can be viewed from the second viewing zone is that of the picture elements optically aligned with the polarization adjusting means of the second group.

The optical system preferably comprises at least one lens provided between the at least one pair of sources of light and the SLM. The at least one lens may comprise an array of lenses.

The light of the first and second polarizations may be plane polarized light, the axis of polarization of the light of the first polarization being perpendicular to that of the light of the second polarization.

Alternatively, the light of the first and second polarizations may be circularly polarized light, the device preferably further comprising means for converting the light of the first and second polarizations to plane polarized light, conveniently a quarter wave plate.

The picture elements of the SLM adjacent the first group of polarization adjusting means are preferably arranged to display a different picture to those adjacent the second group of polarization adjusting means.

The array of polarization adjusting means may comprise a one dimensional alternating array, or alternatively, the first and second groups of polarization adjusting means may, for example, be arranged in a checkerboard-like two dimensional array.

The pair of light sources may comprise a single light source and polarizing means for converting the light emitted therefrom, in use, to light of the first polarization and light of the second polarization.

The array of polarization adjusting means may comprise an array of polarizing elements, an array of wave plates arranged to rotate the axis of polarization of light incident thereon by $90(2n+1)°$ where n is an integer, and/or an array of quarter wave plates arranged to convert the polarization of incident light from circular polarization to plane polarization.

The invention will further be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic perspective view illustrating a display device according to a first embodiment of the invention;

Figure 2 is a view similar to Figure 1 of a second embodiment;

Figure 2a is an enlarged view of part of the embodiment of Figure 2;

Figure 2b is a view similar to Figure 2a of a modification;

Figure 3 is a plan view of a third embodiment;

Figure 4 is a plan view of a fourth embodiment;

Figure 5 is a plan view of a fifth embodiment;

Figure 6 is a plan view of a sixth embodiment;

Figure 7 is a diagrammatic view illustrating the SLM of the display device of Figure 1;

Figures 8 to 11 are views similar to Figure 7 of alternative SLMs;

Figure 12 is another diagrammatic view of the SLM of Figure 7; and

Figure 13 is a view illustrating a programmable light source suitable for use with the display device of Figure 1.

The display device illustrated in Figure 1 comprises an illumination system in the form of a pair of light sources 1, 2 arranged to emit plane

polarized light, the axis of polarization of the light emitted by one of the sources 1 being perpendicular to the axis of polarization of the light emitted by the other source 2. The emitted light is incident upon an optical system comprising a lens 3 arranged to image the light so as to produce an image of the first light source 1 at a first viewing zone 6a and an image of the second light source 2 at a second viewing zone 6b spaced from the first viewing zone. The lens 3 is of the type which does not affect the polarization of light incident thereon.

The light transmitted by the lens 3 is incident upon a spatial light modulator (SLM) 4 in the form of a liquid crystal device comprising a plurality of liquid crystal picture elements each of which is arranged to modulate the light intensity, a control device (not shown) being arranged to control the SLM 4 in order to produce the desired display.

The SLM further comprises an array of polarization adjusting means 5 (see Figures 7 to 11) each of which is adjacent and aligned with a respective picture element of the SLM 4. The polarization adjusting means are of two types, one type 5a being substantially transparent to light of the polarization of the first light source 1 and substantially opaque to light from the second light source 2, and the other type 5b being substantially transparent to light from the second light source 2 but substantially opaque to light from the first light source 1. This effect is achieved in the SLM illustrated in Figure 7 by arranging the first layer of polarizing elements so that the polarizing elements of the first type 5a have their axes of polarization parallel to the polarization axis of the first light source 1 and the polarizing elements of the second type 5b have their polarization axes parallel to the axis of polarization of the second light source 2. It will be recognised that since the polarization axes of

the light sources 1, 2 are perpendicular to one another, so are the polarization axes of the first and second types 5a, 5b of polarizing element. In the Figure 1 embodiment, the polarizing elements are arranged in a checkerboard fashion, but the polarizing elements could alternatively be arranged in stripes of alternating polarization, for example.

In use, the control device is arranged so that the picture elements adjacent to the polarizing elements of the first type 5a display one of a pair of stereoscopic pictures, which is visible at a first viewing position, the other being displayed by the remaining picture elements and visible from a second viewing position. By positioning himself so that one eye is at or near to the first viewing position and the other eye is at or near to the second viewing position, the observer will see the full stereoscopic image without requiring the use of viewing aids.

If the light sources 1, 2 are moved, the locations of the viewing positions will also move. By moving the light sources 1, 2, it is therefore possible to provide a display device in which a moving observer always sees the stereoscopic image, the light sources 1, 2 being arranged to move so that the viewing positions track the observer. The content of the image may also be adjusted upon detection of movement of the observer in order to provide an image look around facility.

The illumination and optical systems of the device illustrated in Figure 2 differs from those illustrated in Figure 1 in that the pair of light sources and lens of the Figure 1 embodiment are replaced by an illumination system comprising a single extended light source or "backlight" (not shown), and a polarizing panel 10 having polarizing stripes 10a, 10b

provided thereon, and an optical system comprising a lenticular screen 11. The stripes 10a, 10b of the polarizing panel comprise a plurality of stripes of a first polarization 10a separated by stripes of a second polarization 10b having their axes of polarization perpendicular to those of the stripes of the first polarization 10a. Figure 2a shows the arrangement of the stripes 10a, 10b of the panel 10.

The lenticular screen 11 comprises an array of cylindrical lens elements arranged with their longitudinal axes parallel to the longitudinal axes of the stripes 10a, 10b of the polarizing panel 10. The width of each cylindrical lens element is equal to substantially twice the width of each stripe 10a, 10b of the polarizing panel 10. Thus, it will be recognised that the light of the first polarization transmitted by the lenticular screen 11 will be transmitted in a different direction from that of the second polarization in order to provide first and second viewing positions as described above.

The SLM 4 is provided adjacent the lenticular screen 11 and arranged to modulate the incident light to form the desired image. As in the Figure 1 embodiment, the SLM 4 comprises a liquid crystal display device having a plurality of switchable picture elements, and an array of polarization adjusting elements arranged so that each polarization adjusting element is adjacent a respective picture element of the SLM 4. Half of the polarization adjusting elements are arranged to transmit light of the first polarization substantially preventing transmission of light of the second polarization, the other half of the polarization adjusting elements being arranged to transmit light of the second polarization whilst substantially preventing the transmission of light of the first polarization. The two types of polarization adjusting element are arranged in a one

dimensional alternating array similar to the polarizing panel 10, although other configurations, for example, a two dimensional checkerboard array may be used.

In use, light of the first polarization is transmitted by the lenticular screen 11 in a first direction and can be viewed from a first viewing position. Since the light can only pass through some of the polarizing elements, the image formed at the SLM and visible from the first viewing position is that displayed by the picture elements of the SLM 4 which are adjacent the polarizing elements of the first type. Similarly, light of the second polarization is transmitted by the lenticular screen 11 in a second direction and can be viewed from a second viewing position. The image displayed on the SLM and visible from the second viewing position is that displayed by the picture elements which are adjacent the polarizing elements of the second type.

If an observer is positioned so that one of his eyes is at the first viewing position and his other eye is at the second viewing position, by controlling the SLM 4 so that the images visible from the first and second viewing positions form the two halves of a stereoscopic pair, the observer sees a three dimensional stereoscopic image without requiring the use of viewing aids. Since the polarizing panel 10 is spaced from the lenticular screen 11, light from one of the stripes of the polarizing panel 10 may be incident upon a cylindrical lens element of the lenticular screen 11 other than the element directly adjacent thereto giving rise to the display device producing a plurality of pairs of viewing zones or "lobes" 6a, 6b. Tracking of a moving observer may be achieved by moving the polarizing panel 10 with respect to the lenticular screen 11.

The polarizing panel of Figure 2b may be used instead of that in Figure 2a, each pair of stripes 10a, 10b of the panel of Figure 2b being separated by an opaque stripe 10c. It will be recognised that by using such a panel, the locations of the pairs of viewing positions 6a, 6b are separated from one another to avoid the situation where each of the observers eyes sees the image intended for the other eye (pseudoscopic zones). Operation of the device is as described with respect to Figure 2.

As an alternative to this arrangement, the lenticular screen 11 may be replaced by a converging lens of the type illustrated in Figure 1. Similarly, the lens 3 of Figure 1 could be replaced by an array of lenses, for example, a lenticular screen. It will thus be recognised that the optical system chosen for use in the display device is largely independent of the illumination system selected.

Figure 3 illustrates an embodiment which comprises a two dimensional array of pairs of polarized light sources 1, 2 (Figure 3a), light from which is incident upon a lenticular screen 11 which comprises a two dimensional array of lens elements. Each lens element is arranged to focus light from a corresponding pair of light sources 1, 2 onto a SLM 4 to be viewed from a pair of viewing positions 6a, 6b. By moving the array of light sources 1, 2 with respect to the lenticular screen 11, the viewing positions 6a, 6b can be arranged to track a moving observer, such tracking being in both a horizontal direction and a vertical direction.

It will be recognised that the embodiments illustrated in Figures 1 to 3 use the SLM of Figure 7, this being the only one of the illustrated embodiments in which the light transmitted by the SLM is of two

orthogonal components, each of the other SLMs transmitting only a single polarization component. The choice of SLM is largely independent of the optical and illumination systems used, and it will be recognised that others of the illustrated SLMs, or indeed other SLMs not described or illustrated herein, could be used. It may be considered to be advantageous to use an SLM of the type which transmits only one of the polarization components as such an SLM does not suffer from intensity variations between the two views of an autostereoscopic image with changes of viewing angle to the same extent as an SLM arranged to transmit two orthogonal polarization components.

The device illustrated in Figure 4 is similar to that illustrated in Figure 1 but includes a beam combiner 20 between the SLM 4 and the observer, a second, identical, SLM 4a, lens 3a and pair of light sources 1a, 2a being arranged to transmit light to the beam combiner 20. The use of the beam combiner 20 allows two pairs of autostereoscopic images to be produced, enabling the observer to view four different 2D views of the image from the appropriate viewing positions to provide a look around facility, or allowing two observers to see the image. If desired, each pair of images being movable independently so as to track respective observers by moving the corresponding pair of light sources 1, 2, 1a, 2a. The beam combiner 20 may comprise a partially reflecting, partially transmitting mirror.

Figure 5 illustrates a display device in which time multiplexing is used in order to enhance the autostereoscopic display. The device is similar to that illustrated in Figure 1 but includes a second pair of polarized light sources 1b, 2b adjacent the pair present in the Figure 1 embodiment. In use, the first pair of light sources 1, 2 are switched on to illuminate the

SLM 4, producing a first pair of images as described above. After a short predetermined time period, the first pair of light sources 1, 2 are switched off, the display of the SLM 4 changed, and the second pair of light sources 1b, 2b switched on so as to produce a second pair of images spaced from the first pair of images. It will be recognised that the device illustrated in Figure 5 is capable of displaying four different images at spaced locations using a single SLM 4. By using an SLM 4 capable of very rapid display changes and pairs of light sources 1, 2, 1b, 2b which can be switched at a suitably high speed, a substantially flicker free display can be provided. Displays capable of displaying more images, for example sixteen images, may also be produced in this manner with a sufficiently high frame rate SLM 4.

The display device illustrated in Figure 6 is similar to that of Figure 1, but instead of being arranged to be viewed directly, a projection lens arrangement 7 is provided to project the images onto a lenticular screen 8 so that when viewed from zone 6a, the observer sees one of a stereoscopic pair of images and when viewed from zone 6b, the other image of the stereoscopic pair is seen. The display device illustrated in Figure 6 has the advantage that a relatively large image can be produced.

Other types of projection configuration may be used, for example as described in GB 9323402.9. In addition, the polarization adjusting means may be spaced from the plane of the liquid crystal layer of the SLM 4, for example by being provided on the outer surface of the glass substrate thereof. A further alternative is to position the elements of the polarization adjusting means on the surface of the projection screen 8 rather than on the liquid crystal of the SLM 4.

In the SLM 4 illustrated in Figures 7 to 11 which is shown in the undriven state of the TN mode and is suitable for use in any of the devices described above, a liquid crystal layer 30 which is used to modulate the incident light is provided between a pair of glass substrates 31a, 31b which are provided with electrodes (not shown) operable under the control of a suitable control unit (not shown). The liquid crystal layer 30 comprises a layer of TN type liquid crystal material, although other materials may be used. The electrodes are arranged so as to define a plurality of picture elements, the liquid crystal material of each picture element being switchable independently of the remaining picture elements. Suitable alignment layers (not shown) are provided for aligning the liquid crystal material in its undriven state.

A first array of polarizing elements 5a, 5b is provided between one of the substrates 31a and the liquid crystal layer 30, each polarizing element 5a, 5b being aligned with a respective picture element. A second array of polarizing elements 32a, 32b is provided between the liquid crystal layer 30 and the other substrate 31b. As shown in Figure 7, the polarizing elements 5a, 5b, 32a, 32b on each side of the liquid crystal layer 30 are arranged so that their axes of polarization are perpendicular to one another. In Figures 7 to 11, an upwardly directed arrow denotes plane polarized light of one polarization, a dot representing plane polarized light having its polarization axis perpendicular to the polarization represented by the arrow, propagating in the direction shown.

In use, the light incident on the SLM 4 is a mixture of light of the first polarization and light of the second polarization. At each element 5a, 5b of the first array, one of the polarizations is transmitted, the other

being substantially absorbed or reflected, the light transmitted by the first array of polarizing elements 5a, 5b passing through the liquid crystal layer 30 where its axis of polarization is rotated so as to extend perpendicular to the original direction. On leaving the liquid crystal material, since the direction of polarization has been rotated, the light will be transmitted by the second layer of polarizing elements 32a, 32b.

Figure 7 shows adjacent pairs of polarizing elements of the two arrays, in each case showing which polarization of light is transmitted and which is not transmitted. Although Figure 7 shows the incident and transmitted rays as being parallel to one another, it will be recognised that the rays of light of the first polarization may not be parallel to the rays of light of the second polarization, light incident on the pixels from each of the light sources being spread over a range of angles.

The SLM of Figure 8 is similar to that of Figure 7, the second array of polarizing elements 32a, 32b having been replaced, for one polarization, by half wave plates 33 which rotate the axis of polarization of the incident light so that the polarization axis extends perpendicularly to the original direction. The polarizing elements of the other polarization are replaced by compensation plates 34 which simply occupy the space between the liquid crystal layer 30 and the glass substrate 31b, not affecting the polarization of the light passing therethrough.

The outer surface of the second glass substrate 31b is provided with a plane polarizing plate 35 having its axis of polarization extending parallel to the polarization axes of the polarizing elements 5b aligned with the half wave plate 33. This arrangement has the advantage that only one array of polarizing elements 5a, 5b is required.

The SLM 4 shown in Figure 9 is similar to that illustrated in Figure 8 but the positions of the liquid crystal layer 30 and the half wave plates 33 (and compensation plates 34) are reversed so that light passes through the liquid crystal layer 30 after having passed through a half wave plate 33 or compensation plate 34.

The SLM 4 of Figure 10 is similar to that of Figure 9, the positions of the half wave plates 33 (and compensation plates 34) and the polarizing elements 5a, 5b having been reversed. In addition, the array of polarizing elements 5a, 5b has been replaced by a single plane polarized sheet 36 having its axis of polarization perpendicular to the axis of polarization of the sheet 35 on the outer surface of the second substrate 31b. In this embodiment, substantially all of the incident light passes through the half wave plates 33 and compensation plates 34, only one component thereof being transmitted by the polarized sheet 36, the selection of which component of the original incident light is transmitted being dependent upon which of the half wave plate 33 and compensation plate 34 the light passes through.

Figure 11 illustrates an SLM 4 for use with a pair of circularly polarized light sources 1, 2 arranged to emit oppositely handed circularly polarized light. Light emitted by the sources 1, 2 passes through a glass substrate 31a and is incident upon an array of quarter wave plates 50, 51 arranged to convert the light from circular polarization to plane polarization. Half of the quarter wave plates 50 are arranged to convert left handed circularly polarized light to plane polarized light of the type denoted by an arrow, right handed light being converted to plane polarized light denoted by a dot. The other half of the quarter wave plates 51 are arranged to convert right handed light to plane polarized light denoted

by an arrow, converting left handed light to plane polarized light denoted by a dot.

Light transmitted by the quarter wave plates 50, 51 is incident upon a polarizer 36 arranged to transmit only plane polarized light of the type denoted by an arrow, the transmitted light passing through a liquid crystal layer 30, glass substrate 31b and being incident upon a polarizer 35 arranged to transmit plane polarized light denoted by a dot.

In use, in one state of the liquid crystal layer 30, the polarization of light transmitted thereby is rotated by 90°, substantially all of the light transmitted by the polarizer 36 also being transmitted by the polarizer 35. In another state, the liquid crystal layer 30 does not alter the polarization of light, substantially no light being transmitted by the polarizer 35.

In each of the above described SLMs, each picture element is arranged to control the transmission of light of one polarization and substantially prevent transmission of light of the other polarization. Each of the described SLMs could be used in any of the devices of Figures 1 to 6. Although the polarization adjusting means are only described as being arranged in stripes or in a checkerboard pattern, other patterns may be used but it is preferable for there to be approximately equal numbers of elements of the first type and elements of the second type and for the two types to be substantially evenly spread out in order to produce two images of substantially equal brightness and quality.

Colour filters may be incorporated into the device in order to provide a colour display, and suitable positions for incorporating such colour filters are indicated in the drawings.

Figure 12 shows one possible configuration of the polarizing elements of a liquid crystal display device. As illustrated, the polarization adjusting elements may be incorporated with the colour filters in a single layer.

In each of the described embodiments, the SLM includes a liquid crystal layer for modulating the light incident thereon. It will be recognised that other transmissive spatial light modulators may be used.

Figure 13 shows a programmable plane polarized light source suitable for use in the display device of Figures 1 to 6. The polarized light source comprises a source 40 of non-polarized light arranged to transmit light towards a polarizing plate 41. The polarizing plate 41 is substantially transparent to plane polarized light of a first polarization and substantially opaque to plane polarized light having a polarization axis perpendicular to the first polarization. Light from the polarizing plate 41 is incident upon a liquid crystal device which comprises a first glass substrate 43 carrying a first electrode and alignment layer, a liquid crystal layer 42 and a second glass substrate 44 carrying a second electrode and alignment layer. The liquid crystal layer 42 may comprise a layer of TN liquid crystal material.

In use, the electrodes are used to switch the liquid crystal layer 42 between its fully driven state and its fully undriven state. In its driven state, the plane polarized light transmitted by the polarizing plate 41 passes through the liquid crystal layer 42 without having its axis of

polarization altered by the liquid crystal material. In the undriven state, the axis of polarization of the light passing through the liquid crystal layer 42 is rotated by 90°, the transmitted light having a polarization axis perpendicular to the light incident on the liquid crystal device.

It will be recognised that by controlling the liquid crystal device using a suitable controller (not shown), the device can be used to produce two sources of polarized light, the polarization axes of which are perpendicular to one another. When used in a display device in which it is desirable to track the observer, the effective positions of the polarized light sources can be changed without physically moving the light source by switching the liquid crystal material between its fully driven and fully undriven states.

Where the SLM is of the type arranged to transmit components of light of crossed polarization, for example the SLM illustrated in Figure 7, it will be recognised that by replacing the pair(s) of polarized light sources with a light source arranged to emit light of random polarization, or by a polarized light source arranged to emit light polarized at an angle, preferably 45°, to both the first and second polarization, the image can be viewed from a large number of locations provided viewing aids, for example spectacles having polarized lens of cross polarization, are used. It will thus be recognised that a switchable display capable of displaying autostereoscopic images visible from a relatively small number of viewing positions or stereoscopic images visible from a relatively large number of viewing positions is possible.

CLAIMS

1. An autostereoscopic display device comprising a source of light of a first polarization, a source of light of a second polarization different from the first polarization, an optical system arranged to image the light emitted by the light sources through a spatial light modulator (SLM) to produce an image of the source of light of the first polarization at a first viewing zone and an image of the second source of light at a second viewing zone, the SLM including a plurality of picture elements arranged to modulate the light emitted by the sources of light, and a plurality of polarization adjusting means each being optically aligned with at least one respective picture element, the polarization adjusting means comprising a first group arranged to permit the transmission of light of the first polarization and substantially prevent transmission of light of the second polarization, and a second group arranged to permit the transmission of light of the second polarization and substantially prevent transmission of light of the first polarization such that the image on the SLM which can be viewed from the first viewing zone is that of the picture elements optically aligned with the polarization adjusting means of the first group and the image which can be viewed from the second viewing zone is that of the picture elements optically aligned with the polarization adjusting means of the second group.

2. An autostereoscopic display device as claimed in Claim 1, wherein the picture elements of the SLM adjacent the first group of polarization adjusting means are arranged to display different image information to those adjacent the second group of polarization adjusting means.

3. An autostereoscopic display device as claimed in Claim 1 or Claim 2, wherein the SLM comprises a liquid crystal device.

4. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the optical system comprises at least one lens.

5. An autostereoscopic display device as claimed in Claim 4, wherein the at least one lens is provided between the at least one pair of sources of light and the SLM.

6. An autostereoscopic display device as claimed in Claim 4 or Claim 5, wherein the optical system comprises an array of lenses.

7. An autostereoscopic display device as claimed in Claim 6, wherein the array of lenses comprises a lenticular screen consisting of a plurality of elongate lens elements.

8. An autostereoscopic display device as claimed in Claim 6, wherein the array of lenses comprises a two dimensional array of lenses.

9. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the source of light of the first polarization and the source of light of the second polarization are movable in order to permit movement of the first and second viewing zones.

10. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the at least one pair of light sources comprises a single source of light and polarizing means for converting the light

emitted therefrom to light of the first polarization and light of the second polarization.

11. An autostereoscopic display device as claimed in Claim 10, wherein the polarizing means comprises a striped polarizing panel having stripes arranged to transmit light of the first polarization alternating with stripes arranged to transmit light of the second polarization.

12. An autostereoscopic display device as claimed in Claim 10, wherein the polarizing means comprises a striped polarizing panel comprising a repeating series of stripes arranged to transmit light of the first polarization, stripes arranged to transmit light of the second polarization, and substantially opaque stripes.

13. An autostereoscopic display device as claimed in Claim 10, wherein the polarizing means comprises a polarizing sheet and a liquid crystal layer switchable between a state in which the polarization of light passing through the liquid crystal layer is not altered and a state in which the liquid crystal rotates the polarization axis by $90(2n+1)^\circ$ where n is an integer.

14. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the first and second groups of polarization adjusting means are arranged in a one dimensional alternating array.

15. An autostereoscopic display device as claimed in any one of Claims 1 to 13, wherein the first and second groups of polarization adjusting means are arranged in a two dimensional array.

16. An autostereoscopic display device as claimed in Claim 15, wherein the two dimensional array is a checkerboard-like array.

17. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the light of the first polarization comprises plane polarized light and the light of the second polarization comprises plane polarized light having its axis of polarization perpendicular to that of the light of the first polarization.

18. An autostereoscopic display device as claimed in any one of Claims 1 to 16, wherein the light of the first polarization comprises circularly polarized light of one handedness, and the light of the second polarization comprises circularly polarized light of the opposite handedness.

19. An autostereoscopic display device as claimed in any one of the preceding claims, wherein the polarization adjusting means comprises absorbing polarizer means.

20. An autostereoscopic display device as claimed in Claim 19, wherein the absorbing polarizer means comprises an array of polarizing elements arranged so that elements of one polarization type form part of the first group, and elements of an orthogonal polarization type form part of the second group.

21. An autostereoscopic display device as claimed in Claim 19 or Claim 20, wherein the polarization adjusting means further comprises a second array of polarizing elements each of which is aligned with a respective polarizing element of the first array.

22. An autostereoscopic display device as claimed in Claim 17, wherein the first group of polarization adjusting means comprise half wave plates arranged to rotate the axis of polarization of light incident thereon by 90(2n+1)° where n is an integer.

23. An autostereoscopic display device as claimed in Claim 22, wherein the second group of polarization adjusting means comprise compensation plates.

24. An autostereoscopic display device as claimed in Claim 22 or Claim 23, wherein the polarization adjusting means further comprises an array of polarizing elements.

25. An autostereoscopic display device as claimed in Claim 24, wherein the array of polarizing elements is adjacent the wave plates.

26. An autostereoscopic display device as claimed in Claim 24, wherein the array of polarizing elements is separated from the wave plates by an active layer of the SLM.

27. An autostereoscopic display device as claimed in Claim 22 or Claim 23, further comprising a polarizing panel provided adjacent the half wave plates.

28. An autostereoscopic display device as claimed in Claim 18, wherein the first group of polarization adjusting means comprises quarter wave plates arranged to convert a first handedness of circularly polarized light to a first plane polarization type and the second group of polarization adjusting means comprises quarter wave plates arranged to

convert the opposite handedness of circularly polarized light to said first plane polarization type.

29. An autostereoscopic display device as claimed in Claim 28, further comprising a polarizing panel adjacent the quarter wave plates.

30. An autostereoscopic display device as claimed in any one of Claims 22 to 29, wherein the polarization adjusting means further comprises an output absorbing polarizer.

31. An autostereoscopic display device as claimed in any one of the preceding claims, further comprising at least one beam combiner, and at least one further source of light of the first polarization and source of light of the second polarization, optical system and SLM.

32. An autostereoscopic display device as claimed in any one of the preceding claims, further comprising at least one additional pair of light sources, the first mentioned sources of light and the additional light sources being arranged to be illuminated in an alternating fashion, the SLM displaying a different image when each pair of light sources is illustrated in order to achieve a time-multiplexed display.

33. An autostereoscopic display device as claimed in any one of the preceding claims, further comprising an optical projection system arranged to project the images onto a lenticular array.

34. An autostereoscopic display device substantially as hereinbefore described with reference to any one of the accompanying drawings.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)** 24	Application number GB 9425607.0
Relevant Technical Fields (i) UK Cl (Ed.N) H4F (FDD) (ii) Int Cl (Ed.6) H04N (13/00, 13/04, 15/00)	Search Examiner MR J M McCANN Date of completion of Search 15 FEBRUARY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) WPI	Documents considered relevant following a search in respect of Claims :- 1

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0541374 A1 (SHARP) see abstract	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).